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USAF ltr, 25 Jan 1972

PRELIMINARY SUMMARY REPORT ON MILROW

13 February 1970

Prepared For
AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D. C.

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Under
Project VELA UNIFORM

Sponsored By
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PRELIMINARY SUMMARY REPORT ON MILROW

SEISMIC DATA LABORATORY REPORT NO. 246

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INTRODUCTION

This report presents a preliminary evaluation of the seismic data for the nuclear explosion MILROW which was available at the Seismic Data Laboratory on 10 December 1969. MILROW is the name given to the large underground nuclear explosion, reported yield of about one megaton, detonated on Amchitka Island in the Aleutians at 22:06:00.04Z, 2 October 1969 (Table I).

This analysis includes location determinations, amplitude, and magnitude estimates for MILROW and compares them to the results for LONG SHOT, an 80 kiloton explosion.

With regard to epicenter determination, we compare the initial location determination for MILROW, to the initial location determination for LONG SHOT using Herrin 68 travel time curves without travel time anomalies. Further, we employ a station network common to MILROW and LONG SHOT to locate the epicenter of each event with and without travel-time anomalies.

The report compares amplitude measurements, magnitude estimates, and phases received for MILROW with those from LONG SHOT when possible. The preliminary measurements provide an opportunity to determine what gross differences, if any, are readily apparent between a large explosion (MILROW) and a smaller one (LONG SHOT), from the same epicentral region.

LOCATION

Microfilm recordings for nine Long Range Seismic Measurements (LRSM) stations and VELA Observatories were originally read for arrival times at the Seismic Data Laboratory (SDL) for the MILROW event. These were supplemented by 125 arrival times for USC&GS reporting stations taken from the U.S. Department of Commerce, ESSA, <u>Earthquake Data Report</u> (EDR) No. 649-69, 22 October 1969. The arrival times for all 134 stations are presented in Table II. Arrival times for the LONG SHOT event are those indicated in SDL Report No. 234. All the networks used in locating MILROW and LONG SHOT in this report have good azimuth coverage (approximately 300 degrees aperture).

The MILROW event was first located using program SHIFT, the Herrin-68 travel time tables, and arrival times for all 134 stations. The resultant shift from the known location was 22.7 km on an azimuth of 339° (Figure 1). This compares favorably with the 328 station location for LONG SHOT which moved 20.6 km on an azimuth of 345°.

Next, a common network of 73 stations which recorded both MILROW and LONG SHOT, including eight LRSM and observatories, was used to locate the two events. The errors in location are very similar (Figure 1) to those obtained with the total network. MILROW shifted 21.8 km on an azimuth of 333° while LONG SHOT shifted 22.7 km on an azimuth of 335°. The similarity is not surprising as the networks both have the same azimuthal coverage, are large in number of stations, and the common network is a subset of the LONG SHOT and MILROW networks. It should be noted that the common network solutions within reading error, exhibit the same separation

as the actual locations.

Travel-time anomalies were determined for the common station network using the Herrin-68 travel time tables and are plotted against station name in Figure 2. The stations are arranged in order of azimuth. The anomaly points are arbitrarily connected in the figure but this does not imply that a continuous function exists. There are two gaps in the data occurring between stations PAS and MOK and between BAH and BRS. These gaps are 54° and 63° wide, respectively.

The common network solutions for MILROW and LONG SHOT shift similarly. The events are very close to each other, and the travel-time anomalies for the two events are very nearly the same. Thus, one should be able to locate MILROW using anomalies determined from LONG SHOT and similarly locate LONG SHOT with anomalies determined from MILROW. The exercise was conducted with the following results. MILROW shifted 1.2 km on an azimuth of 21° and LONG SHOT shifted 0.9 km on an azimuth of 190° (Figure 1). The two vectors are very short and nearly mirror images of each other. Thus we conclude that MILROW and LONG SHOT are in the same travel-time anomaly region and the "bias" does not change from one site to the other for the 73 station common network used.

AMPLITUDE AND MAGNITUDE ESTIMATES

The amplitude and magnitude estimates were determined by visual analysis of LRSM and VELA observatory film records available at the SDL and where amplitudes are not measurable on film, magnetic tape playouts are used. Amplitudes are reduced to particle velocity (A/T) in millimicrons/second. Magnitudes are computed using the standard Gutenberg formulas. These data are tabulated in Table III and include all operational LRSM and VELA observatory seismograms available to the SDL.

Figures 3 and 4 show body wave and surface wave magnitudes respectively for MILROW, and for LONG SHOT stations common to MILROW. The MILROW magnitudes, in general, show the same pattern of variance between stations as do the corresponding LONG SHOT magnitudes. Further the difference between body wave and surface wave magnitude is $(m_b - M_s) = (6.41 - 4.69) = 1.72$ for MILROW and $(m_b - M_s) = (5.85 - 4.06) = 1.79$ for LONG SHOT. Therefore, little or no difference in the relative excitation between P and Rayleigh wave is observed between the two events.

Figures 5 through 10 show the measurable amplitudes for P, long-period P, PcP, Love Waves, Rayleigh waves, and P'P'. For LONG SHOT, only P, PcP and Rayleigh waves were consistently present. However, for MILROW the presence of long period P, and P'P' implies a difference in size of source dimensions, an expected result since the yield of MILROW is an order of magnitude greater than that of LONG SHOT. The presence of Love waves suggests the occurrence of tectonic strain release, but other equally valid explanations exist.

SUMMARY AND CONCLUSIONS

1. The initial location of MILROW made using 134 stations indicates a shift of 22.7 km at an azimuth of 339° from the actual epicenter. LONG SHOT epicenter was shifted 20.6 km at an azimuth of 345° using 328 stations.

Employing a common network of 73 stations for MILROW and LONG SHOT, epicenter shifts of 21.8 km and 22.7 km at azimuths of 333° and 335° were obtained.

Travel-time anomalies determined for MILROW and applied to LONG SHOT, and vice versa gave locations of about 1 km from the actual epicenters. Thus the location problems are identical to those encountered for LONG SHOT. However, LONG SHOT calibrated the Amchitka region in terms of travel-time anomalies and an accurate location of MILROW is possible with the use of mostly telegraphic data. Further, we would expect little improvement with detailed redetermination of arrival times.

2. Relative excitation between body and Rayleigh waves for MILROW and LONG SHOT are similar and in terms of differences between P wave and Rayleigh wave magnitudes $(m_b - M_s) = (6.41 - 4.69) = 1.72$ (21 station averages) for MILROW and $(m_b - M_s) = (5.85 - 4.06) = 1.79$ for LONG SHOT.

3. In addition to P, PcP, and Rayleigh waves observed for LONG SHOT, long-period P, P'P', and Love waves are observed for MILROW. The presence of long-period P and P'P' would be expected since the yield of MILROW is an order of magnitude greater than LONG SHOT and the presence of Love waves suggests some type of tectonic strain release may have occurred.

TABLE 1

Event Description

Date: 02 October 1969

Time of Origin: 22:06:00.039Z

Yield: About one megaton, AEC press release No. M-225, 24 September 1969

Magnitude: m_b = 6.41 (determined from 21 LRSM and VELA stations)

M_s = 4.69 (determined from 21 LRSM and VELA stations)

Location: Amchitka Island, Aleutian Islands

Coordinates:

Latitude: 51°25'02"N

Longitude: 179°10'56"E

Environment:

Geologic Medium: Tuff (?)

Surface Elevation: 130 feet above mean sea level

Shot Depth: 3992 feet.

TABLE II

Arrival time data used in locating MILROW
in order of increasing azimuth

Event Name *02OCT69 MILROW

Latitude 51.418N Longitude 179.187E

134 Stations

STATION	ARRIVAL TIME	STATION	ARRIVAL TIME	STATION	ARRIVAL TIME
NOR	22 14 29.90	YKC	22 13 1.60	PG2BC	22 12 47.90
IFR	22 19 22.40	SCM	22 10 41.20	CPO	22 16 45.70
RBA	22 19 19.00	PMR	22 10 29.50	SES	22 13 52.80
AVE	22 19 22.80	MNT	22 16 36.70	CAR	22 19 27.00
KTG	22 15 48.10	WES	22 16 59.80	LAO	22 14 31.30
ALE	22 13 57.10	OTT	22 16 30.60	HHM	22 13 48.50
BRW	22 10 59.60	BEC	22 18 5.00	NTI	22 13 33.50
NP-NT	22 12 44.40	BIG	22 9 52.00	PNT	22 13 17.00
MBC	22 12 44.20	RK-ON	22 15 3.60	NEW	22 13 34.00
RES	22 13 36.00	GEO	22 16 58.70	TUL	22 16 5.50
FBC	22 15 20.40	CLE	22 16 31.80	BMO	22 13 48.80
TNN	22 10 36.90	MRG	22 16 46.50	TJC	22 15 24.00
FB-AK	22 10 48.90	AAM	22 16 20.90	UBO10	22 14 47.10
PJD	22 10 51.50	CHC	22 17 7.00	BHP	22 18 59.80
GIL	22 10 50.60	KDC	22 10 .60	DUG	22 14 32.50
BLC	22 14 1.10	CHI	22 16 8.00	JCT	22 16 15.00
COL	22 10 50.00	SJG	22 19 1.00	ALQ	22 15 26.90
LLR	22 10 53.80	TRN	22 19 39.60	EUR	22 14 21.50
HN-ME	22 16 50.40	EDM	22 13 32.30	KN-UT	22 14 48.45
SFA	22 16 37.20	SIT	22 11 38.20	LC-NM	22 15 39.20
FCC	22 14 28.50	DBQ	22 15 54.20	SSS	22 18 11.10
SVW	22 9 57.20	ORT	22 16 48.60	QUI	22 19 36.00

TABLE II (Cont'd.)

Arrival time data used in locating MILROW
in order of increasing azimuth

STATION	ARRIVAL TIME	STATION	ARRIVAL TIME	STATION	ARRIVAL TIME
COM	22 17 53.00	THT	22 17 36.80	DDR	22 12 30.00
TFO60	22 15 9.20	GNZ	22 18 58.00	OIS	22 13 2.00
MIN	22 13 49.00	KRP	22 18 55.80	SAP	22 11 40.30
MMA	22 15 9.10	CRZ	22 18 40.00	SHL	22 17 1.00
TUC	22 15 20.80	RIV	22 18 53.80	NDI	22 17 41.40
FHC	22 13 35.70	BRS	22 18 20.20	JER	22 19 4.50
JAS	22 14 5.80	TOO	22 19 16.20	BUD	22 18 8.88
UKI	22 13 47.60	RAB	22 16 7.20	NUR	22 16 48.00
MDC	22 13 59.10	CTA	22 17 52.30	SOD	22 16 3.00
SLD	22 14 6.70	KDB	22 16 52.00	ZAG	22 18 19.60
MHC	22 14 3.50	PMG	22 16 51.00	VKA	22 18 6.00
OLC	22 13 53.50	GRK	22 16 35.50	PRU	22 17 57.70
HCC	22 14 5.10	KLG	22 19 27.50	UPP	22 16 37.30
CRC	22 14 1.20	GUA	22 14 28.20	KHC	22 18 3.20
STC	22 14 9.30	DAR	22 17 48.00	KIR	22 16 4.50
PRI	22 14 14.90	MUN	22 19 43.00	CLL	22 17 49.70
PAS	22 14 36.00	MEK	22 19 18.50	FUR	22 18 9.00
MOK	22 12 53.60	DAV	22 16 22.90	MOX	22 17 55.50
OPA	22 12 51.50	QCP	22 15 59.00	GRF	22 18 1.70
KIP	22 12 53.10	BAG	22 15 51.00	COP	22 17 27.00
HON	22 12 54.40	TSK	22 12 23.60	STU	22 19 7.20
BAH	22 12 53.70	SRY	22 12 32.10	KRL	22 18 6.30
				BNS	22 17 55.80
				BER	22 17 .20

Table III

Principal Phases

CODE	STATION	DISTANCE (KM)	DEGREES	INST.	MAGNIFICATION (K) FILM x 10	PHASE	TRAVEL TIME OBSERVED (MIN)	(SEC)	PERIOD T SEC	MAXIMUM AMPLITUDE A/T	MAGNITUDES M_b	M_s	COMMENTS
FB-AK	Fairbanks, Alaska	2394	21.5	SPZ	11.8	P	04	48.9	0.5	1610.0	6.36		
				SPN	13.2	S	08	38.0	1.2	208.0			
				SPZ	11.8	PcP	08	50.3	0.6	72.3			
				SPN	13.2	PcS	12	26.8	1.3	95.5			
				SPN	13.2	ScS	16	07.8	1.2	21.5			
				SPZ	11.8	P'P'	38	42.9	1.2	23.8			
				LPZ	13.5	LPP			10.5	370.0			
				LPZ	13.5	LPS_V			06.5	1760.0			
				LPN	13.1	LPS_H			11.5	264.0			
				LPZ	13.5	LR			-	-			CLIPPED*PTS
WH-YK	Whitehorse, Yukon	2969	26.7	SPZ	NO GAIN*	P	05	38.4	0.8				No film available and no calibration on tape for this day.
				SPZ		PP	06	22.3	1.0				
				SPZ		PcP	09	02.5	0.9				
				SPT		S	10	20.0	1.2				
				LPR		LQ			20.0				
				LPZ		LR			20.0				
NP-NT	Mould Bay, Northwest Terr.	3786	34.0	SPZ	269.0*	P	06	44.2	0.6	170.0	5.93		*Magnetic tape playout
				SPZ	2.4	PcP	09	(30.0)	1.2	267.0			
				SPZ	269.0*	P'P'	37	46.4	1.2	58.5			
				SPZ	269.0*	P'P'	39	09.5	1.2	20.9			
				LPT	15.5	LPP			20.0	24.7			
				LPT	15.5	S	12	20.0	20.0	34.5			
				LPR	26.5	LQ			23.0	19.5			
				LPZ	1.85	LR			20.0	193.0		4.95	
PG-BC	Prince George, British Columbia	3844	34.6	SPZ	12.8	P	06	47.7	1.2	188.0	5.97		
				SPZ	12.8	e	06	53.2	1.2	188.0			
				SPZ	12.8	PcP	09	23.4	1.0	1035.0			
				SPZ	12.8	ScP	13	08.0	1.0	19.5			
				SPR	14.2	S	13	12.2	1.1	36.8			
				LPR	15.0	LQ			28.0	44.6			
				LPZ	14.1	LR			22.0	90.5		4.62	
BMO	Blue Mountain, Oregon	4037	41.7	SPZ	27.0	P	07	48.6	1.1	1045.0	6.52		
				SPZ	27.0	PcP	09	45.2	1.2	208.0			
				SPZ	27.0	P'P'			1.2	12.5			
				LPZ	1.20	LR			20.0	91.6		4.45	
BP-CL	Bishop, California	5029	45.2	LPZ	59.7	LR			21.5	18.1		4.12	Station inoperative at P time
UBO	Uinta Basin, Utah	5446	49.0	SPZ	240.0	P	08	47.1	1.0	100.0	5.80		
				SPZ	240.0	PcP	10	11.0	0.8	76.5			
				SPZ	570.0	P'P'	39	10.0	1.4	22.6			
				SPZ	570.0	P'P'	40	37.4	1.4	26.3			
				LPE	50.0	LQ			27.0	23.2			
				LPZ	11.0	LR			25.0	40.9		4.53	
KNUT	Kanab, Utah	5455	49.1	SPZ	17.9	P	08	48.4	1.2	2070.0	7.12		
				SPZ	17.9	e	08	54.6	0.8	308.0			
				SPZ	17.9	e	09	03.4	1.2	1210.0			
				SPZ	17.9	PcP	10	12.5	0.8	842.0			
				SPT	18.9	S	15	56.8	1.6	48.6			
				LPR	19.5	LQ			22.0	49.5			
				LPZ	23.0	LR			15.0	146.0		5.09	
RK-ON	Red Lake, Ontario	5726	51.5	SPZ	22.7	P	07	03.6	1.7	944.0	6.65		
				SPZ	22.7	e	10	07.5	1.0	87.5			
				SPZ	22.7	e	10	43.6	1.0	87.5			
				LPZ	22.0	LPP			(21.0)	(7.80)			
				LPR	9.55	S			20.0	6.52			
				LPZ	22.0	LR			21.5	329.0		5.06	
TFO	Tonto Forest, Arizona	5761	51.8	SPZ	5.50	P	09	09.2	0.9	661.0	6.32		
				SPZ	5.50	PcP	10	22.6	1.3	275.0			
				LPZ	(7.00)	LR			20.0	(42.9)		(4.59)	
LC-NM	Las Cruces, New Mexico	6222	56.0	SPZ	25.0	P	09	39.0	1.0	137.0	5.94		
				SPZ	25.0	PcP	10	57.2	0.8	161.0			
				SPZ	25.0	PKKP	23	57.4	1.0	20.0			
				LPT	25.6	S	27	55.0	17.0	16.0			
				LPZ	22.1	(OLR)			19.0	36.8			
				LPZ	22.1	(LR)			15.0	37.7		4.59	

Table III

Principal Phases

Code	Station	Distance (km)	Degrees	Inst.	Magnification (K) Film x 10	Phase	Travel-Time Observed (min)	(sec)	Period T sec	Maximum Amplitude A/T	Magnitudes m_b	M_s	Comments
CR-NB	Crete, Nebraska	6253	56.2	SPZ	13.0	P	09	38.8	0.7	461.0	6.47		
				SPZ	13.0	PcP	10	33.4	0.7	338.0			
				LPZ	2.60	LPP			(14.0)	(30.2)			
				LPR	5.80	(LQ)			(21.0)	(22.1)			
				LPZ	2.60	LR			18.0	60.6		4.5	
BY-IO	Bloomfield, Iowa	6518	58.6	SPZ	8.00	P	09	55.0	0.8	805.0	6.71		
				SPZ	8.00	PcP	10	(42.0)	0.8	106.0			
				SPZ	50.0	(P'P')	39	35.0	(1.0)	(20.0)			
				LPR	3.40	LQ			21.0	14.1			
				LPZ	15.0	OLR			24.0	30.8			
				LPZ	15.0	LR			20.0	43.4		4.72	
WQ-IL	Watseka, Illinois	6838	61.2	SPZ	24.0*	P	10	13.8	0.6	79.2	5.91		*Magnetic tape playout
				SPZ	19.0	PcP	10	54.8	0.6	77.7			
				LPZ	130.	LPP			13.0	5.63			
				LPR	17.6	S	19	25.0	18.0	71.9			
				LPT	11.0	LQ			24.0	15.5			
				LPZ	16.0	LR			19.0	97.9		5.06	
GI-OH	Galion, Ohio	7105	63.4	SPZ	34.5*	P	10	31.6	0.5	144.0	6.16		*Magnetic tape playout
				SPZ	28.0	PcP	11	06.0	0.8	118.0			
				SPZ	28.0	P'P'	39	18.0	1.0	71.5			
				LPZ	33.0	LPP			(20.0)	(4.64)			
				LPZ	33.0	OLR			25.0	21.8			
				LPZ	27.0	LR			19.0	15.7			
SJ-TX	San Jose, Texas	7162	64.4	SPZ	60.9*	P	10	38.0	0.7	346.0	6.54		*Magnetic tape playout
				SPZ	60.9*	e	10	59.0	1.0	123.0			
				SPZ	60.9*	PcP	11	09.0	1.0	73.8			
				SPZ	55.0	e	11	24.0	1.3	258.0			
				SPZ	55.0	e	11	52.1	1.2	151.0			
				SPZ	55.0	P'P'	39	22.8	1.5	28.2			
				LPZ	2.90	LPP			(17.0)	(25.0)			
				LPT	3.70	LQ			18.5	27.3			
				LPZ	2.40	LR			19.0	20.0		4.41	
GR-MS	Greenville, Mississippi	7188	64.6	SPZ	3.00	P	10	37.8	1.0	835.0	6.92		
				LPR	1.30	LQ			23.0	312.0			
				LPZ	2.40	LR			20.0	26.6		4.54	
CPO	Cumberland Plateau, Tenn.	7351	66.1	SPZ	5.00	P	10	45.7	0.7	(959.0)	(6.98)		
				SPZ	5.00	PcP	11	15.0	0.6	288.0			
				SPZ	40.00	P'P'	39	22.0	1.3	25.2			
				LPE	3.00	LQ			30.0	33.3			
				LPZ	3.10	LR *			18.0	204.0		5.4	
EU-AL	Eutaw, Alabama	7432	66.8	SPZ	25.0	P	10	51.8	(0.8)	(184.0)	(6.27)		
				SPZ	25.0	PcP	11	19.0	1.0	56.1			
				SPT	562.	e	22	22.0	1.1	93.7			
				SPZ	287.	P'P'	39	(20.0)	1.1	10.2			
				LPT	8.00	LQ			(20.0)	(4.14)			
				LPZ	9.00	LR			(19.0)	(9.33)		(4.11)	
AS-PA	Altoona, Pennsylvania	7548	66.1	SPZ	147.0*	P	10	50.4	2.2	1570.0	7.14		
				SPZ	50.0	e	11	25.4	1.0	142.0			
				SPZ	50.0	(PcP)	39	(13.0)	1.3	26.2			
				SPZ	255.0	P'P'			20.0	132.0		5.26	
				LPZ	25.0	PP							
HN-ME	Houlton, Maine			LPT	6.40	LQ	10	45.7	0.5	269.0	6.41		*Magnetic tape playout
				LPZ	2.50	LR	11	05.6	0.8	84.5			
		7444	67.0	SPZ	21.2	P	11	20.0	0.8	69.9			
				SPZ	21.2	PcP	39	18.4	1.2	29.6			
				SPZ	21.2	P'P'			23.0	25.8			
				LPZ	12.5	LR			28.0	42.2			
									43.0	21.5		4.48	
PT-PA	Pottstown, Pennsylvania	7553	67.9	SPZ	20.0	P	10	57.4	1.0	560.0	6.74		
				SPZ	20.0	PcP	11	55.8	0.6	59.9			
				SPZ	110.0	P'P'	39	21.0	1.1	34.6			
				LPR	310.0	(LQ)			28.0	1.68			
				LPZ	(110.0)	LR			22.0	12.3		(3.23)	
BE-FL	Belleview, Florida	8124	73.1	SPZ	16.0	P	11	29.7	0.7	236.0	6.27		
				SPZ	16.0	PcP	11	47.4	0.8	138.0			
				LPR	4.80	LQ			19.0	43.7			
				LPZ	5.80	LR			23.0	26.0		4.62	

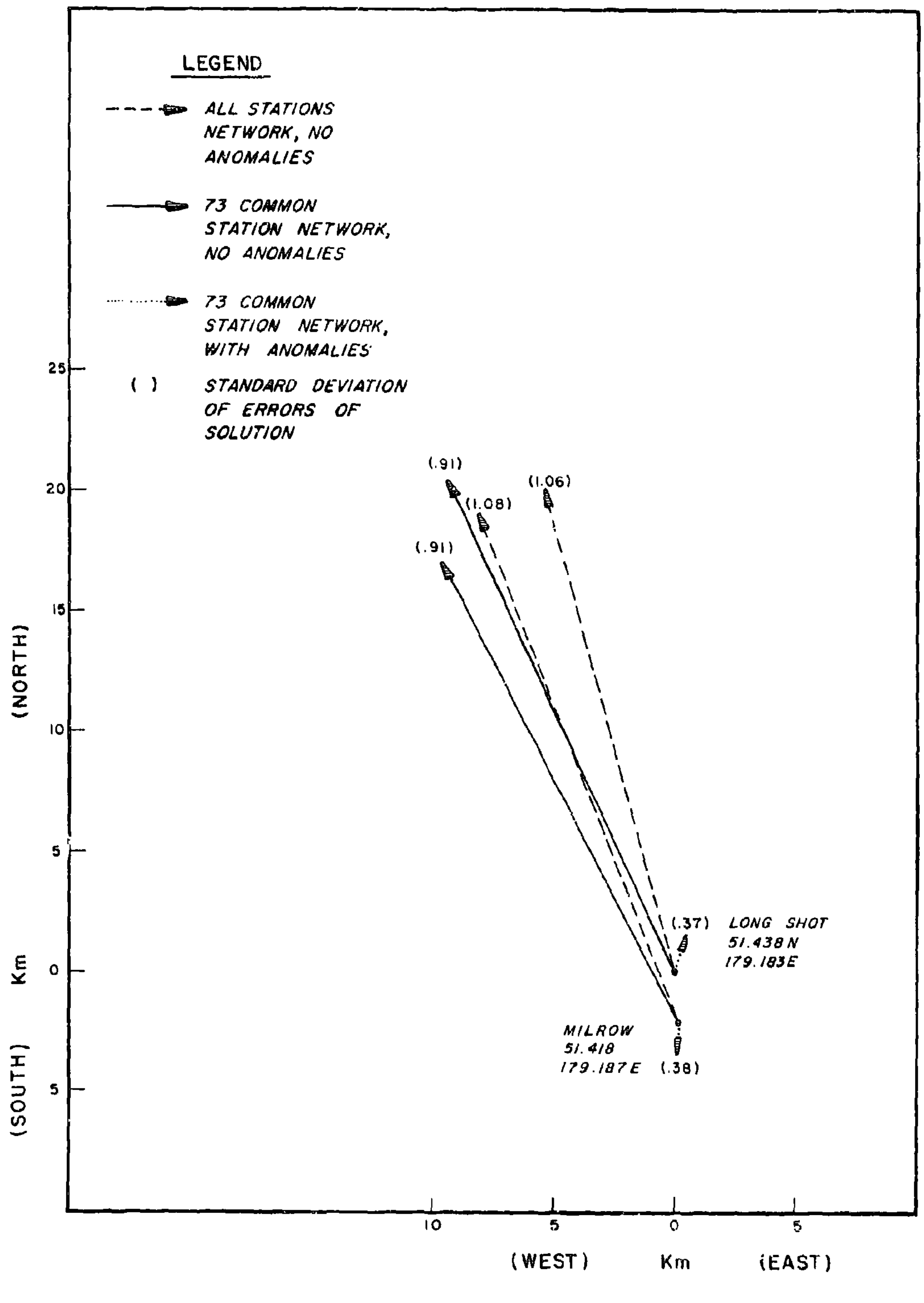

Figure 1. Location results for LONG SHOT and MILROW using Herrin-68 travel-time tables with and without travel- ime anomalies.

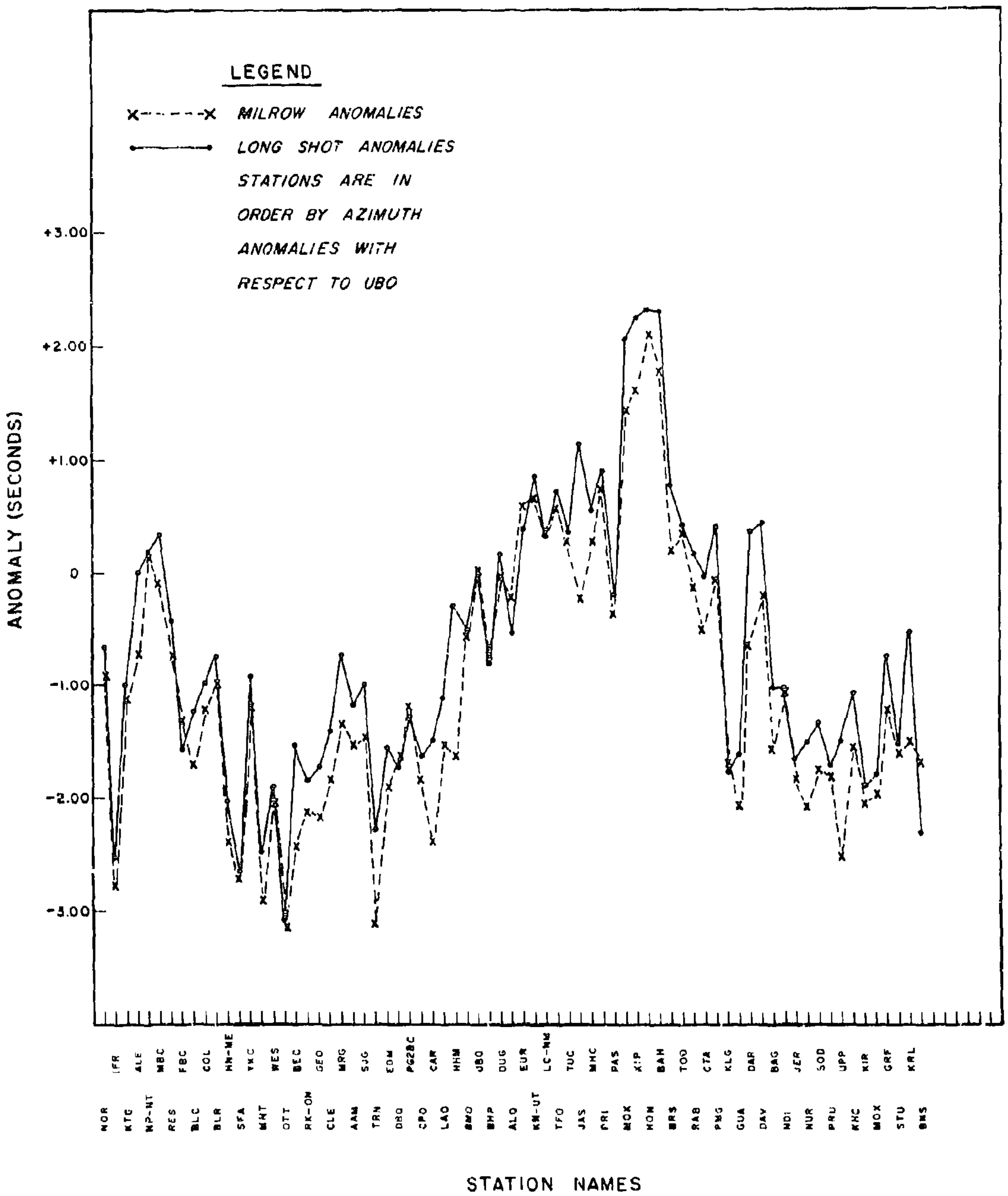

Figure 2. Comparison of LONG SHOT and MILROW travel-time anomalies.

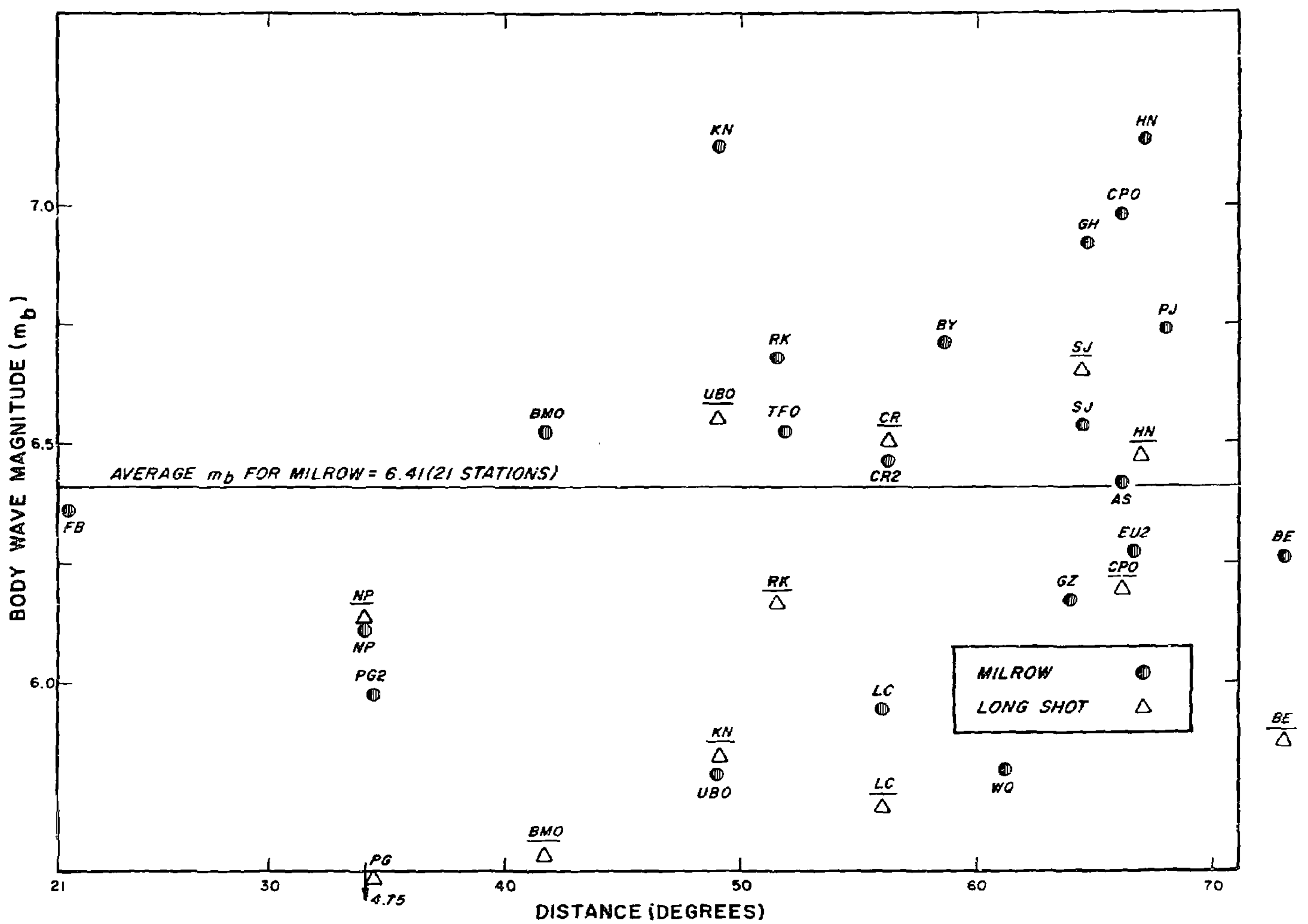

Figure 3. Body wave magnitudes, MILROW and LONG SHOT.

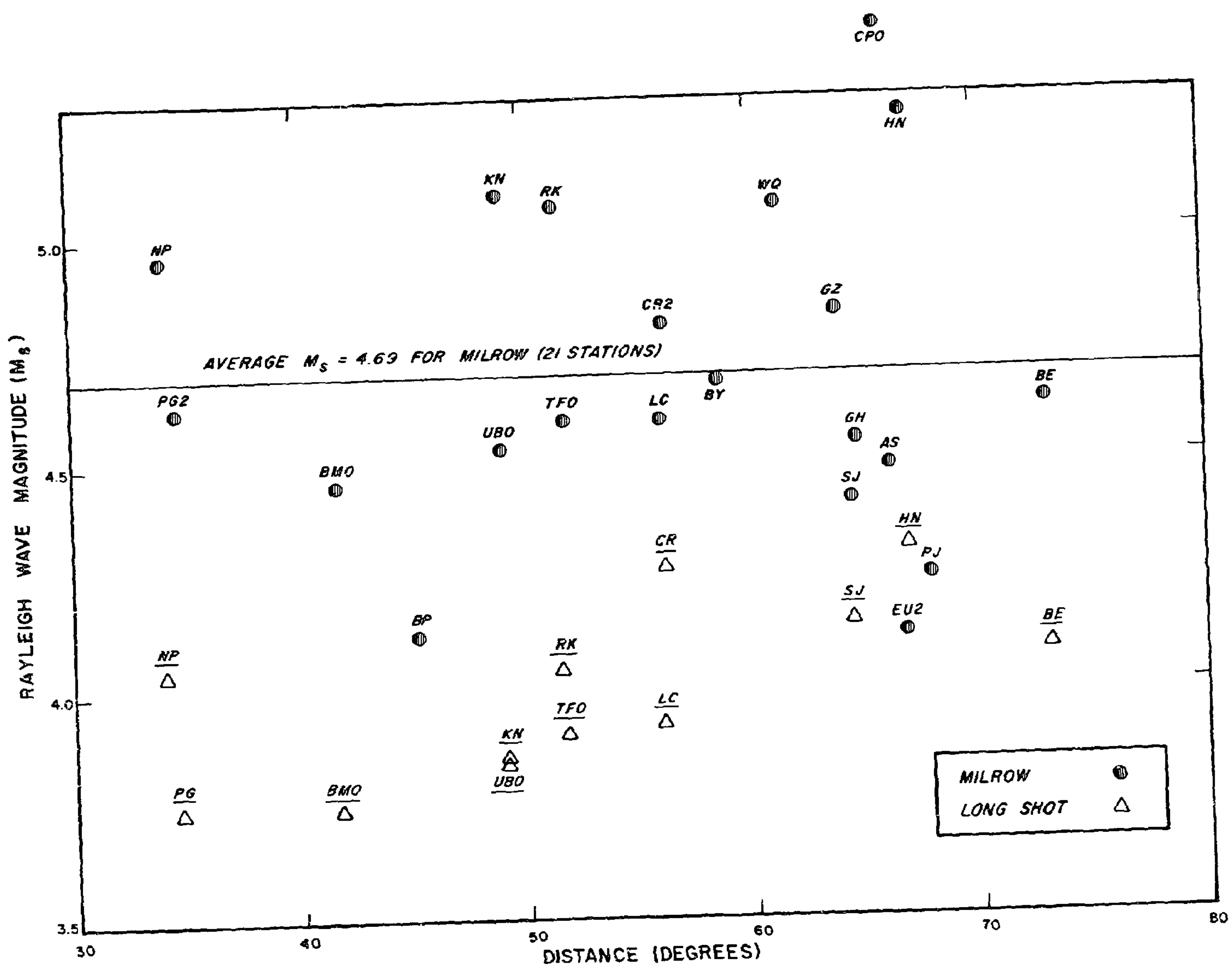

Figure 4. Rayleigh wave magnitudes, MILROW and LONG SHOT.

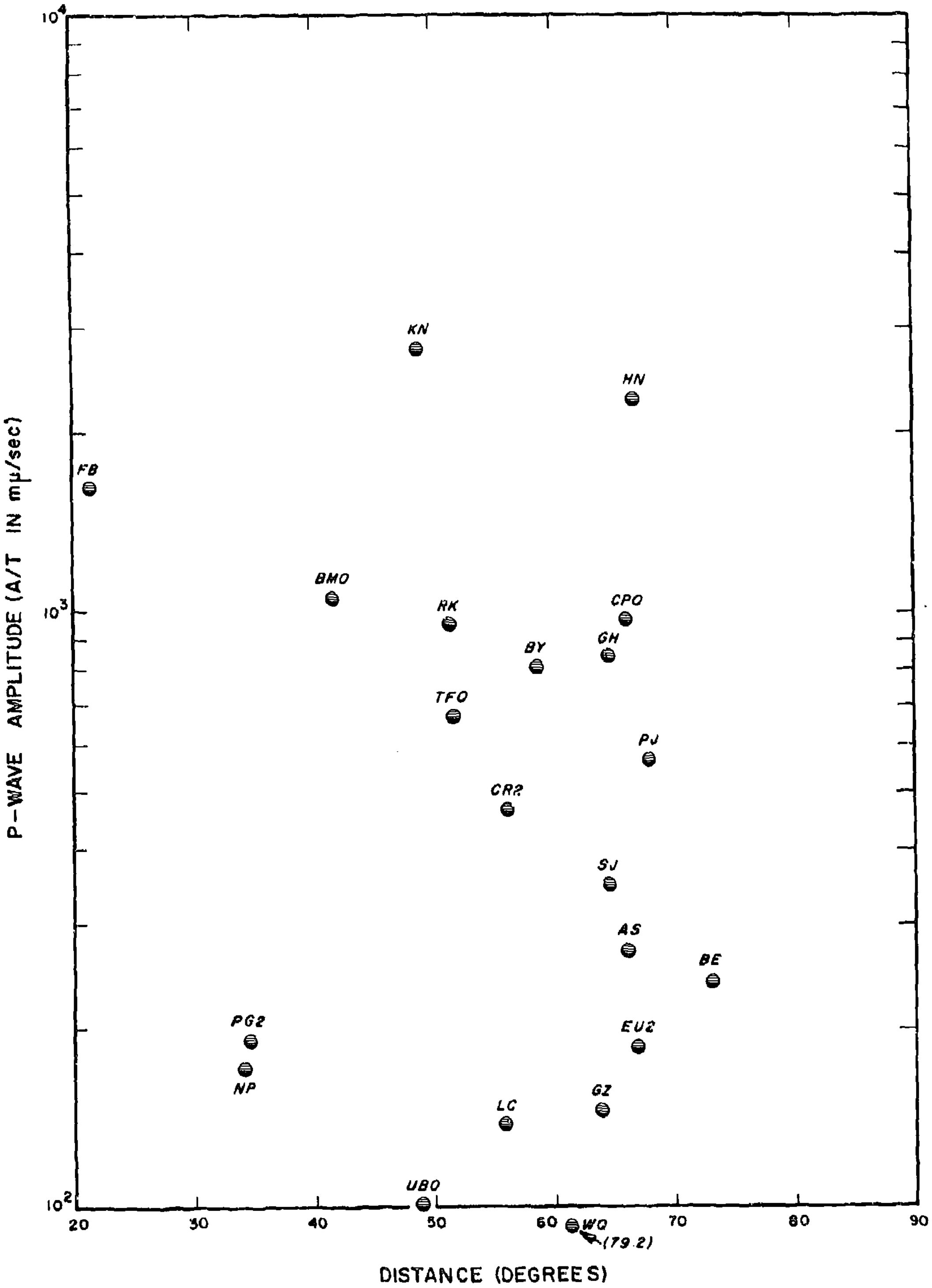

Figure 5. MILROW P-wave amplitudes.

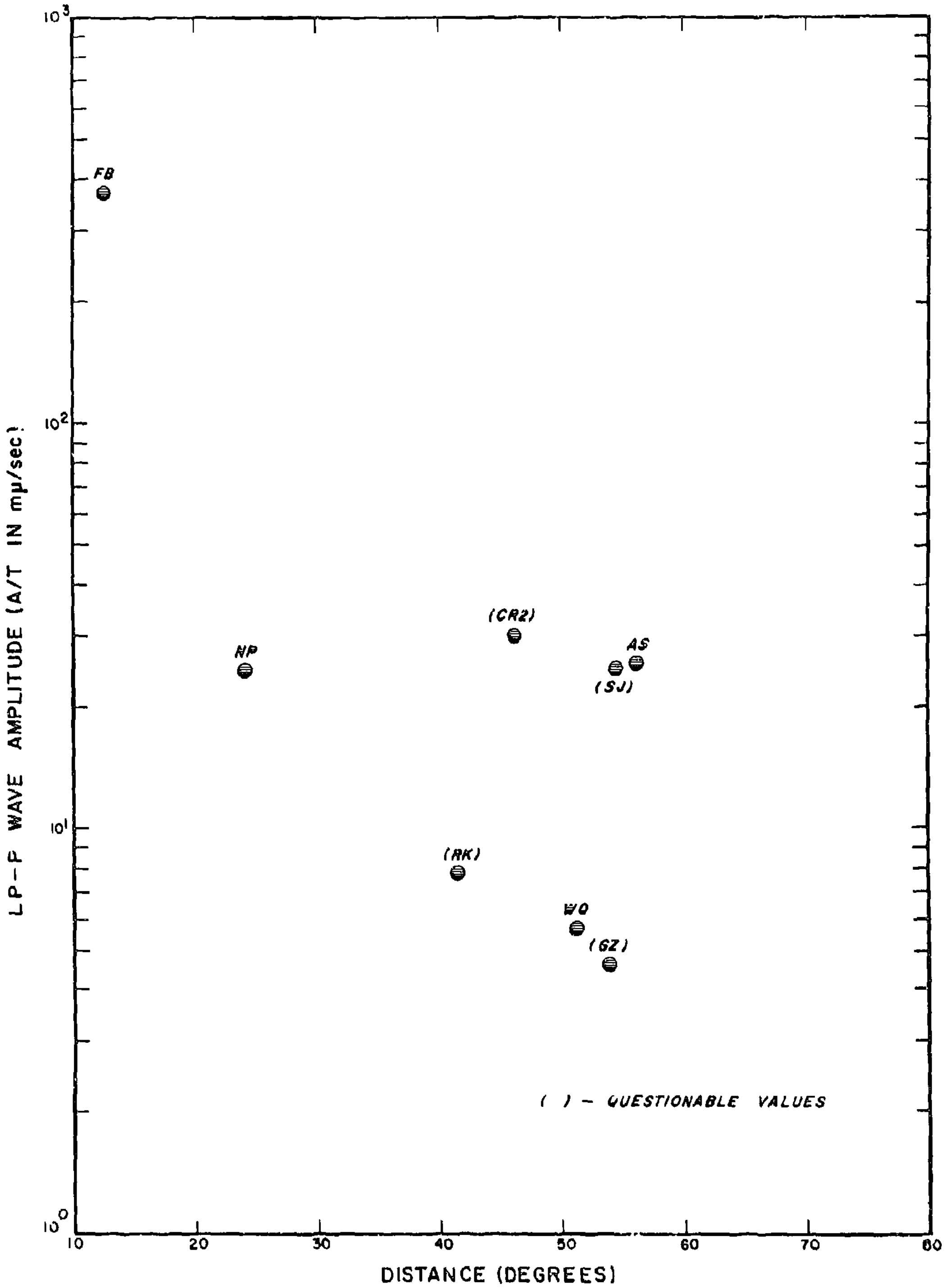

Figure 6. MILROW long period P-wave amplitudes.

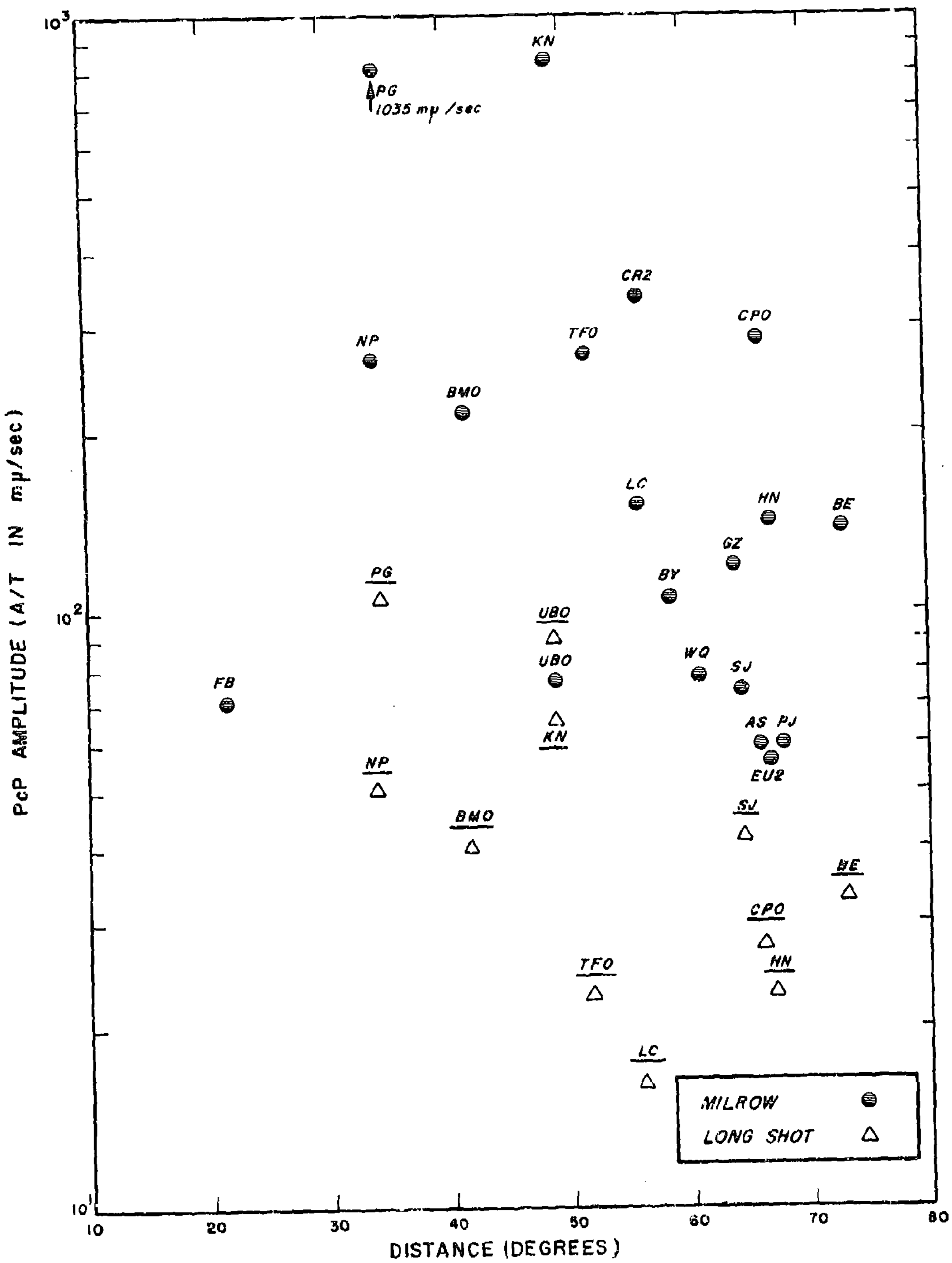

Figure 7. PcP amplitudes, MILROW and LONG SHOT.

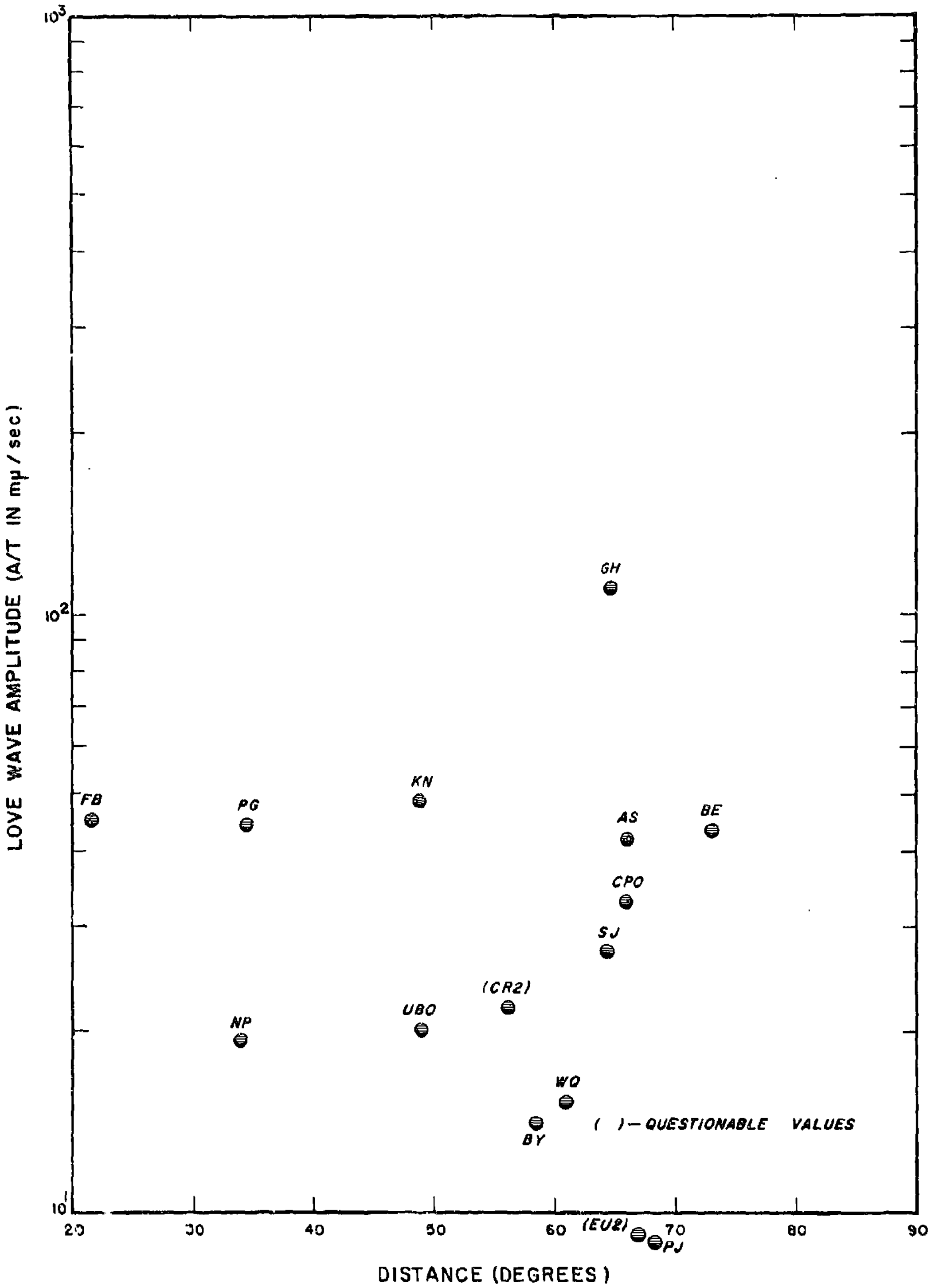

Figure 8. Love wave amplitudes for MILROW.

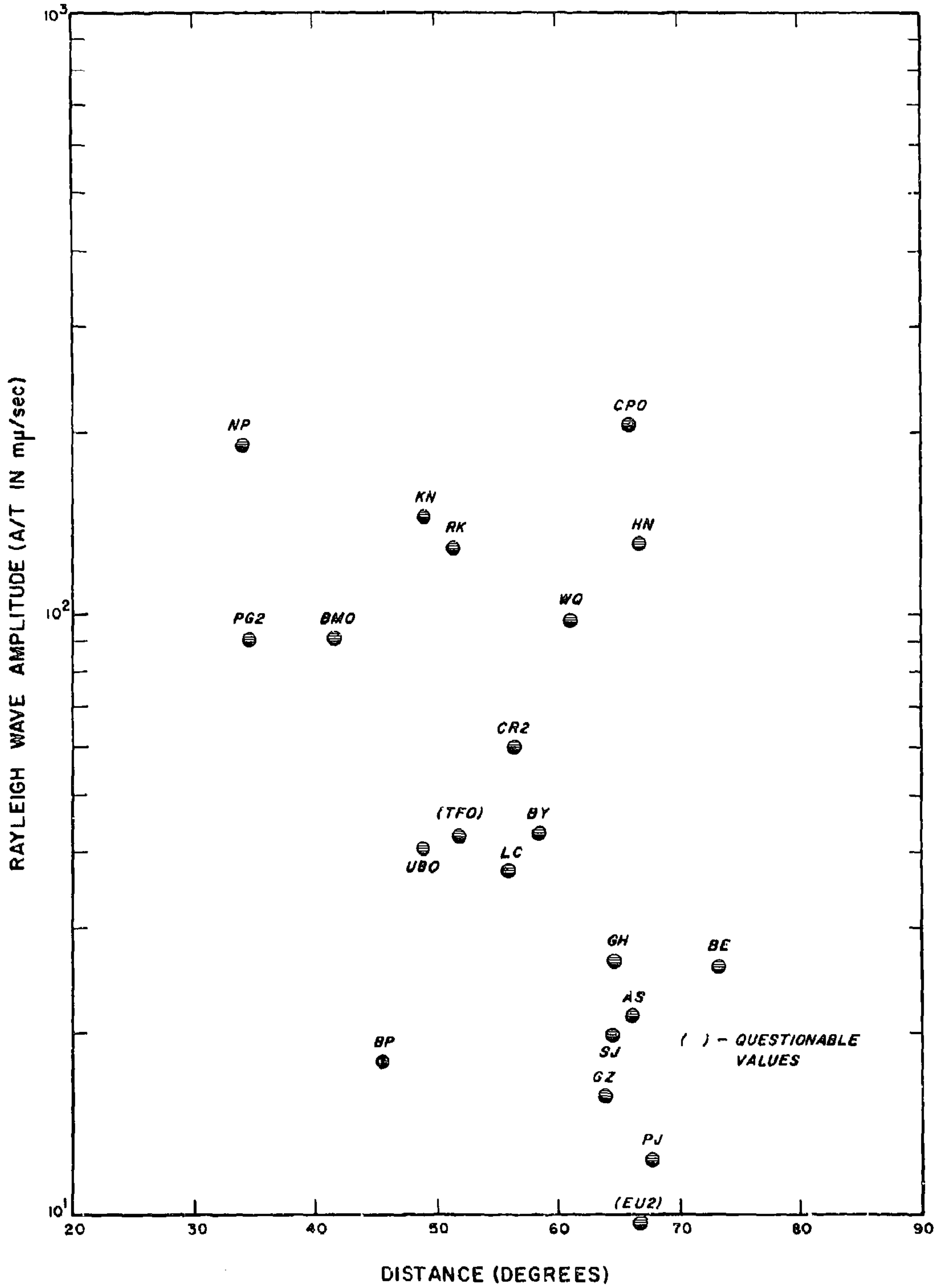

Figure 9. Rayleigh wave amplitudes for MILROW.

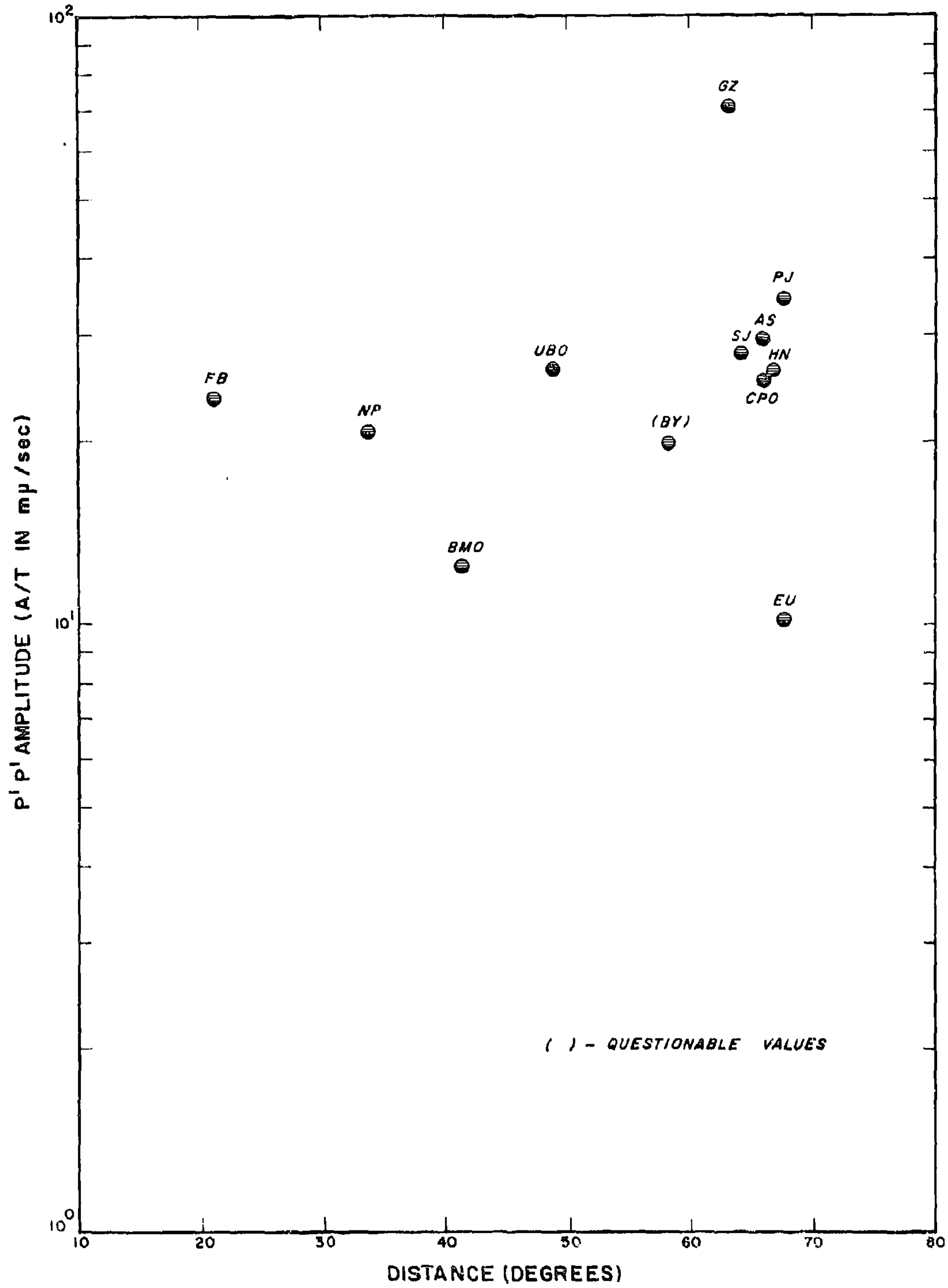

Figure 10. P'P' amplitudes for MILROW.

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